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On the relations of certain fall to spring blossoming plants.

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(WITH PLATES I AND II.)

Most spring flowering plants in the more northern latitudes begin the development of their floral organs already during the previous year. The following table will give a very good idea of the extent to which this development has taken place in a series of plants collected near Clarendon, Vermont, during the week from the twenty-second to the twenty-eighth of August. In this list are inserted two plants: *Cypripedium parviflorum* Salisb. collected near Ludlow, Vermont, on the twenty-seventh of September, and *Chimaphila maculata* Pursh, found near Andover, New Jersey, on the ninth of October. The first column indicates whether the scaly winter-buds are subterranean (S), subaerial, or chiefly covered with fallen forest leaves or surrounded by moss (SA), or aerial (A). The second column gives the regular flowering season. The third records the length (in millimeters) attained by the flower cluster at the dates when examined. In the case of *Arisaema triphyllum* Torr. the length of the spathes was given instead (S). The fourth column records the size of the largest flower bud in these clusters. In two cases measurements were not recorded (d).

Hepatica acutiloba DC.	S	Mh. Ap.	——	1.50
Thalictrum dioicum L.	S	Ap. My.	2.3	.42
Actæa alba BIGEL	S	My.	d	d
Actæa spicata, var. rubra MICHX.	S	My.	2.5	.50
Caulophyllum thalictroides MICHX.	S	My.	2.5	.83
Waldsteinia fragarioides TRATT.	SA	Jn.	2.7	2.00
Mitella diphylla L.	S	My. Jn.	.8	.25
Gaylussacia resinosa TORR. & GR.	A	My. Jn.	.8	.17
Vaccinium Pennsylvanicum LAM.	A	My. Jn.	——	1.00
Epigæa repens L.	SA	Ap. My.	7.5	2.50
Pyrola elliptica NUTT.	A	Jn. Jy.	.8	.25
Pyrola secunda L.	A	Jy.	.8	.33
Chimaphila maculata PURSH.	A	Jn. Jy.	.7	.25
Asarum Canadense L.	SA	My. Jn.	——	2.50

Arisæma triphyllum TORR.	S	Ap.	S. 2.5	d
Orchis spectabilis L.	S	My. Jn.	6.3	2.50
Habenaria viridis, var. bracteata REICH	S	Jn.	4.5	2.00
Habenaria orbiculata TORR.	S	Jn. Jy.	4.5	2.00
Goodyera pubescens R. BR.	A	Jn. Jy.	.5	.10
Corallorhiza multiflora NUTT.	S	Jy. Aug.	3.6	1.50
Cypripedium parviflorum SALISB.	S	My. Jn.	——	8.75
Trillium erythrocarpum MICHX.	S	Ap. My.	——	5.50
Clintonia borealis RAF.	S	Jn.	3.0	1.75
Polygonatum biflorum ELL.	S	Ap. My. Jn.	3.0	.75
Smilacina racemosa DESF.	S	My. Jn.	2.5	.33

In Thalictrum dioicum the inflorescence was in a more advanced state of development than the leaves. The inflorescence of Waldsteinia fragarioides lies in the axil of the upper scales of the scaly bud, or of the lowest succeeding leaf. That of Mitella diphylla has a scaly covering of its own, in addition to the scales of the winter bud in general, to which it stands in the relation of a lateral bud. The inflorescence of Gaylussacia resinosa and Vaccinium Pennsylvanicum is found in the terminal and upper axillary buds. That of Pyrola elliptica, Pyrola secunda, Chimaphila maculata, and Goodyera pubescens is enclosed in a scaly bud which usually lies at the center of a cluster of leaves terminating the apparently flowerless stem; occasionally these buds lie in the axil of one of the upper leaves of the flowering stem.

This early development of the flower buds of the next season permits their ready appearance in spring. It will be noticed, however, from the preceding table that even flowers blooming as late as July and August may develop their buds during the previous summer. Occasionally plants mistake the cold winds of the earlier part of October for winter, and the warm, sunny days of Indian summer for spring. In that case the flower buds prepared for the succeeding spring are rapidly developed and perfected, only to be killed off again by the wintry winds of the following months, so that they fail to ripen their seeds. In addition to the list of plants enumerated at other times, the wild strawberry, *Fragaria Virginiana* Ehrh., was very frequently found in blossom this fall, so that thousands of flowering specimens could have been collected.

In quite a number of cases, when the flora of the whole world is drawn under consideration, plants which used to flower in the spring only have taken up the habit of flowering in the late fall, and have succeeded in ripening their seeds in spite of this habit. They were able to flower already in

the fall owing to the advanced state of development of their buds at this season, even before the habit of flowering in the fall set in. It was only necessary to secure means of perfecting their fruit. To illustrate these phenomena the writer has chosen the three plants having this habit which are most familiar to himself: *Hamamelis Virginiana* L. of the United States, *Hedera Helix* L., and *Colchicum autumnale* L., of Europe, a shrub, a vine and an herbaceous plant respectively, belonging to widely different families.

Hamamelis Virginiana, the witch hazel, usually flowers in October or November, but occasionally, after a cold fall, not until the ensuing spring. The flower buds appear very early, almost simultaneously with the leaves, perhaps, but search was not made for them at so early a date. The specimen figured was collected early in July. It will be noticed that the flower clusters are axillary (fig. 1.) The clusters consist usually of three buds closely arranged around the pointed termination of the little axillary stem (fig. 4.) Each bud is subtended by a small appressed bract which reaches about the same height as the buds; these bracts therefore do not offer full protection to the buds within (figs. 2, 3, 4.) Possibly the bracts completely enclosed the clusters formerly, when the witch hazel flowered only in spring. The defect is remedied by the subcoriaceous character of the exposed portions of the calyx, and the hairy covering to both the calyx and the subtending bracts (figs. 2, 3.) The early development of the flower cluster, its long period of extremely slow development, the subcoriaceous character of the calyx and of the bracts, the hairy covering of the same, all indicate rather a plant which once was obliged to protect its blossoms for spring flowering, than a fall plant which is developing into a spring blossomer, or a summer plant becoming a fall blossomer. The fruit remains small during the winter. It is very coriaceous in character, and in addition has a protection of closely-fitting hairs. Its real development begins first in spring, and the seeds are usually not ripened until late summer.

Hedera Helix, the European ivy, usually flowers in October, but in more southern countries as early as September. The writer has seen no record of its ever blossoming in the spring. It may therefore be assumed to be a plant which has entirely gone over from spring to fall blossoming. The young branches of the ivy do not all cease growth at very nearly the same

time, as is the case with so many trees and shrubs, but some of them are terminated with scaly buds, while others continue growth for several months, and may perhaps even have their tips winter-killed. Terminal scaly buds were noticed at Heidelberg, Germany, as early as June 1, although the date of their first appearance is uncertain. They had every character of an aerial scaly bud destined to survive the winter (fig. 14.) Perhaps the scales were a little too green, not at all coriaceous enough, but formerly while the plant was spring blossoming the case might have been different. Not a trace of an inflorescence was noticed in these buds until the first days of July. Near the middle of the month the inflorescence was quite large in all of the flowering buds, and during the last days of July the inflorescence was rapidly pushing its way out of the scaly bud into the open air, and expanding preparatory to fall flowering. The upper scales of the scaly bud are usually carried up on the common peduncle of the inflorescence to a greater or less extent (fig. 15.) The formation of a scaly bud at an early period, at a time when the leaves have almost reached their full growth, and the quite slow gradual development of this bud, are characters perfectly incomprehensible in a summer-flowering plant, taking up the habit of blossoming in the fall, but are readily understood if the plant be supposed to have changed from a spring to a late autumn-flowering plant. The ivy does not ripen its fruit until the ensuing spring. Its character during winter was not noticed.

Colchicum autumnale usually flowers in October, but when the meadows have been inundated in the fall, or when the fall has been unusually cold, it does not blossom until spring. The first trace of a flower was noticed at Heidelberg, Germany, about the middle of July, but it had evidently been in existence for perhaps a week. At the end of the month the flower bud was still minute. The specimen figured belongs to a much later date, just before the flowering season, and represents the developing blossom. As a means of presenting the morphology of this plant it is much better adapted. The bulb has one side considerably flattened, and the other decidedly convex (fig. 5); the lower portion of the bulb slopes obliquely downwards from the convex surface until it meets the flattened surface at an acute angle (fig. 5.) It consists of two withered, brownish scales enclosing the base of

the flowering stem which has developed into a corm. Removing the scales this corm is seen to give form to the bulb (fig. 6.) Along the middle of the flattened face there is seen to be a broad groove, and at its base there has been developed a sort of lobe. To this lobe is attached a bud (fig. 8), which is really in the axil of the inner of the two withered sheathing scales just removed. If at a sufficiently advanced stage of development the thin cuticle at the base of this bud be removed it will be found to completely cover a large bundle of little roots, many of them already 3 mm. long (fig. 9), ready to take the place of the old roots when their work is done (fig. 5.) A reference to the figures will show that by a more rapid development of the tissues just above the roots on the non-attached side of the bud, this bundle of roots becomes central in the oblique base of the future bulb (figs. 5, 7.) The first scale is a closed sheath (fig. 9.) The second scale is a sheath only at its base, but the sheathing portion elongates considerably during subsequent growth (fig. 10.) The first leaf is also slightly sheathing at the base (fig. 11), and the second leaf is not sheathed at all (fig. 12.) In the plant figured the floral envelopes, the stamens, ovary and styles are all already considerably developed (fig. 13.) It will be noticed that a small internode exists between the second scale and the first leaf (*a*, figs. 11, 12, 13.) When the plant begins to flower in the fall the bud pushes its way along the afore-mentioned groove (fig. 8), and up between the withered sheathing scales to the air. This is mainly caused by the growth of the scales of the bud (figs. 9, 10) of the perianth tube, and of the styles of the flower (fig. 13.) The leaves and ovary do not appear until the next spring. At this time the internode between the second scale and the first leaf (*a*, figs. 11, 12, 13) develops rapidly and carries both the leaves and the fruiting ovary out into the open air, thus solving the question of the proper wintering of the fruit. The nondevelopment of the leaves and fruit until the year following the flowering season is certainly not a character such as might be expected from summer flowering plants turning gradually into autumn or spring flowering ones. However, the appearance of the flowers before the leaves is readily intelligible if the reverse change from a spring to a fall blossomer be supposed, since this is not at all an uncommon occurrence in spring flowering plants, and such a forced development of the flower buds before the lower

leaves is often already indicated in the scaly bud of spring flowering plants during the previous year. It is only one of the extreme results of that tendency which certain plants have of flowering as early as possible, and hence of becoming spring and occasionally fall blossoming plants.

Late fall flowering plants may be divided into two classes. First, those which have developed from summer flowering plants by the increase in the number of internodes, with their appendages, or the gradual retardation of growth. Second, those which have developed from spring blossoming plants by the premature development of buds destined to flower first during the ensuing spring. The first class never had any need of protection to the flower buds against wintry weather, and hence should form no scaly buds for the flowers; moreover, since their flowering buds never lay dormant during the winter season, they should show no traces of a period of rest, between the first growth of the flowering buds and their final development. The second class should preserve traces of a scaly bud, and should show traces of great retardation of growth between the first rapid starting of the flower bud and the final rapid completion of the same, as reminiscences of their former almost dormant state during winter. Moreover, the first class should find all their nearest relatives among the summer flowering plants, and the second class should have their nearest relatives among those which flower immediately in the spring. This is the case with the list of fall flowering plants at hand; since, however, this list is only collected from literature, and the writer has not personally examined the plants in a state of nature, a further discussion of the same is omitted for the present.

That spring blossoming plants are the offspring of summer flowering plants, and that they have obtained the power of flowering so early by decreasing the number of their internodes and by starting the development of their flower buds during the previous year is a well known fact. This is further indicated by the fact that spring plants grade by intermediate species into early and late summer flowering plants. If there are related species flowering in the fall, and they belong to the first class above described, a series of intermediate early and late summer flowering plants is sure to be observed. If a spring flowering plant has close relatives among fall blossomers, and none whatever during the inter-

mediate summer months, the development of the fall flowering species from those blooming in spring, in the manner described above, is very likely to be the case. As a matter of fact, most fall blossoming plants belong to the first class.

The ideal time for the flowering season of plants is in late spring and early summer. In the struggle in the race for existence two tendencies set in. The one is to secure advantage over surrounding plants by increasing in size and thus securing more light, air and room for the development of their own flowers. This tends to result in late summer and in autumn flowering plants. The other is to gain advantage over other plants by the earlier blossoming of their flowers, or by blossoming before the foliage of the trees overhead, or that of the surrounding plants can cut off the light or otherwise interfere with their development. This tends to produce spring flowering plants. Autumn blossoming plants, which are the result of the extreme development of the latter principle, are in one sense of the term freaks of nature. The writer believes, however, from a study of the literature of the flowering seasons of plants, that this freak of fall flowering has become a permanent one for a greater number of plants than botanists usually suppose, and that there should be recognized a distinct division of fall flowering plants whose nearest relatives are with those that blossom in the spring.

If the principle that spring flowering plants are produced from summer flowering plants by the reduction of their internodes, be kept in view, it is evident that this result might be attained through the struggle for light and room *in situ*. The same result would be attained if summer plants should migrate temporarily toward the north, or up mountain sides, since the shortening of the period favorable for vegetation might operate in reducing the number of internodes and in hastening the perfection of the flowering buds, while after these alterations had become permanent, a return to more congenial climates would favor earlier, possibly spring blossoming. Essentially the same conditions would exist *in situ*, if the colder climate of a glacial period should come down from the north. The reduction of the period favorable for floral development would again operate in reducing internodes and in hastening the development of floral buds. The retreat of glacial climate would favor earlier blossoming, in many cases spring blossoming. Plants which were spring blossomers in the far

north before the advance of the glacial climate might be forced during its advance to migrate southward to maintain their existence, and on the retreat of the same might climb up the mountain sides and remain there as witnesses of their former migration. Moreover, plants which formerly had been spring blossomers might during the advance of glacial climate maintain themselves *in situ*, by adapting themselves to the more rigorous climate. On the retreat of the glacial conditions they might have so altered their habits as to be able to maintain their existence only on mountain tops or in the distant north. Migration to these places would therefore set in. It is probable that all these causes have operated in the production of spring blossoming plants. It is impossible to tell in the case of individual plants, to which method their production is to be ascribed. It is sufficient for the present to remember that nature has many means of accomplishing the same result.

Heidelberg, Germany.

The effect of mechanical movement upon the growth of certain lower organisms.

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The effect of external agencies upon the growth of organisms has been thoroughly studied in several of its relations. Of these influences, the relation of temperature to growth, is perhaps the best understood. Other factors, such as the effect of light, of increased and diminished pressure, have also been made the subject of more or less careful study.

To the effect of mechanical movement upon the growth, less attention has been given, nor have the results already obtained been entirely in harmony with one another.

In the following experiments an attempt has been made to find out, (1) what influence mechanical movement has upon growth of cells in regard to size and form; (2) its influence upon growth in regard to increase in number.

The method used in the experiments was as follows:

Two 500 c. c. distilling flasks were half filled with nutrient solutions, sterilized and then inoculated with a small quantity of the germ to be studied. After thoroughly distributing the